

Technical Report: NAVTRADEVCEEN 1-59-1

STUDY, MTMS, STEREO INPUT

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FOREWORD

A study to evolve a density pattern recognition and correlation system that will be capable of scanning stereo aerial photographic information, digitizing this information, and then translating it into elevation profiles is being performed by the National Bureau of Standards under the auspices of the U.S. Naval Training Device Center.

This report was transmitted to the Naval Training Device Center in the form of a letter dated 3 December 1963, which is included in total. The report summarizes work performed through October 1963. Although the study is not yet complete, the nature of the information developed at this stage is believed to be of sufficient value to students of the art to warrant distribution at this time.

The report presents the techniques employed, which include the scanning system developed, the method of quantizing densities, and recording the pictorial information digitally on magnetic tape. Also presented are some digital pictorial printouts obtained from machine processing of the originally scanned pictorial information.

Future work on this program will include further analysis and evolution of a logical scheme for handling density sequences to convert the scanned stereo pair data into elevation profiles; with this information and an x-y plotter, contour lines will be plotted automatically.

Harold Barkan
Project Engineer

U. S. Naval Training Device Center

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

ADDRESS REPLY TO
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25, D.C.

IN YOUR REPLY
REFER TO FILE NO.

12.3

December 3, 1963

Commanding Officer
U.S. Naval Training Device Center
Attention: Code 3314
Port Washington, New York

Reference: Government Order NA 61339-1-59 and Amendments

Dear Sir:

This letter reports progress on this project at the National Bureau of Standards during the bimonthly period of September and October 1963. It includes photographs and drawings of the scanner built under this project, a description of the relationships between the scanned picture formats and the digital data formats on magnetic tape and in the magnetic core word formats used in the computer. Also included are several replicas of computer printouts illustrating the ability of computer programs to process, rearrange, and reduce the scanned data inputs.

DESCRIPTION OF THE SCANNER

The scanner is of the lathe type in which the subject copy is mounted on a drum rotated by the spindle, while the optical system is mounted on the carriage and is made to progress parallel to the axis of the drum by means of a screw driven by the spindle through a gear train. Figure 1 is a photograph of the Scanner, and Figure 2 is a schematic drawing of the Scanning System. The picture is scanned helically, the optical system having advanced a distance equal to one line of the picture, while the drum rotates once. The scanner is thus similar in principle to a facsimile transmitter.

The angular position of the drum corresponding to the x coordinate of the picture is sensed by a second optical system, fixed in position, and focussed on a striped band (the sync band) permanently mounted on the picture drum. A photomultiplier emits a pulse for every stripe on the sync band and thereby determines the discrete spatial intervals at which density readings are taken from the subject photograph.

On the sync band are other markings including a black area where there are no stripes. This area, which is in line with the paper clamp, causes a pause in the data transmission which is recorded on the magnetic tape as an inter-record gap.

It can be seen, then, that there is an inter-record gap corresponding to each traverse of the paper clamp. Stated another way, there is a record on the magnetic tape for every line on the photograph.

OPTICAL SYSTEM

The two separate optical systems, one for sensing the sync bars and the other for sensing the reflection density of elementary areas on the subject photograph, are very nearly alike.

An illuminator of the condenser type floods an area on the paper that includes the small elementary area to be sensed.

The incident angle of the illuminating beam is sufficiently oblique to cause any specular reflection from the photograph to completely escape the objective lens. Thus, the percentage of reflected light entering the objective lens depends only on the diffuse reflection density of the elements on the photograph and is independent of the gloss characteristic of the surface of the paper.

The reflected light from this illuminated area enters an objective lens and is focussed on a disc at the image plane of this objective lens. At the center of the disc is a square aperture of such a size as to admit the light from only that element of the subject photograph that is on the axis of the objective optical system. The light passing through the aperture impinges on the cathode of a photomultiplier whose output circuit delivers a voltage proportional to the luminous flux. These parts are shown in Figure 3.

DIGITAL DATA FORMATS

The electronics system performs the function of converting the analog signal from the picture photomultiplier to a digital recording on the magnetic tape. An analog-to-digital converter performs a conversion each time a pulse from the sync band photomultiplier arrives at the converter's control. The output of the converter appears on three lines, each having two possible levels of voltage, which are subsequently recorded on three tracks of the magnetic tape thus forming an octal character whose value is related to the reflectance of the picture element it represents. For example, the binary character 000 (octal 0) corresponds to a black element, 111 (octal 7) to a white and 100 (octal 4) to an intermediate gray, as shown in Figures 4 and 5.

The three remaining information tracks on the magnetic tape are recorded as zeros, while the seventh track, usually reserved for the parity bit, is recorded with an invariable "one". These "ones" record the output of the sync band and therefore mark a tape record by their presence and an inter-record gap by their absence.

Figure 5 shows a picture element of 1/200 inch square, which is approximate. Figure 6 shows a picture element of 1/192 inch square, which is the actual size now employed. This dimension can be modified or made rectangular instead of square if desired.

Figure 6 shows the relationships between the picture format, magnetic tape format, and computer magnetic core word format.

The relationships may be summarized as follows:

1. Each element on the picture is transcribed as a single character on the magnetic tape.
2. The grayness, or reflectance of the element is recorded as a binary coded octal number, 0 corresponding to black and 7 corresponding to white. Intermediate gray tones are recorded as numbers between 0 and 7, the numbers being closely proportional to the reflectance.

Provision has been incorporated in the electronics to provide manual adjustment of the slope and datum of the photomultiplier output in order to accommodate the range of densities of a given photograph to the range of the digital output.

3. The grayness information is contained in the three least significant bits of a character. The other three information bits are invariable zeros.

4. Each line on the photograph is a record on the tape.

5. Each scanner run is a file. At present, only one file is permitted on a magnetic tape. Thus a new tape is required for each scanner run. However, where pictures are small, a number of them may be pasted up and mounted on the drum, if the overall size of the montage is less than 10" x 10".

PICTORIAL PRINTOUTS

Figures 7 through 11 show several techniques illustrative of the variety of printouts which can be obtained from the digital computer after various methods of programmed data processing of the scanned inputs.

Figure 7, of Abraham Lincoln, illustrates several points. Because there are more columns to the inch than rows to the inch in a computer printer, it is necessary to compress the vertical dimension to maintain the correct ratio of height to width. This was accomplished by tilting the original picture of Lincoln, and photographing it obliquely to compress the height as shown in the inset of Figure 7.

This distorted picture, about the size of a postage stamp, was scanned by the lathe scanner. In this case the computer was used only to convert each octal character into a character selected to correspond roughly in printing density to the original scanned character optical density. Faithful reproduction of the picture demonstrates that the data is properly entered and formatted in the computer memory after passing through the scanner, electronics and magnetic tape into the computer.

Figure 3 shows the ability to process line pictures in a similar manner, and Figure 9 shows a tabular printout of the same type of data after considerable data reduction within the computer.

Figures 10 and 11 show printouts of corresponding pairs of sections of aerial photographs, each about postage stamp size when entered into the scanner. In these the density characters are used to emphasize changes in optical density. It can be seen that the pictures are displaced two lines relative to each other, and the lines encircled correspond.

Instead of the printing characters used, eight digits could have been used, so that quantitative optical density could be read directly at each point. Of interest in connection with this, IBM has provided to the Weather Bureau a 1403 printer with a special numerical font whose printing density is proportional to the digit printed. This satisfies the eye in a gross sense and provides direct quantitative readout at any point in the picture.

Future effort is being concentrated upon the computer programming in connection with the problem of automatically reducing stereo pair data into elevation data and contour plotting on automatic X-Y line plotters.

Very truly yours,

Martin C Stark

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Data Processing Systems Division

Enclosures: List of Figures,
Eleven Figures.

List of Figures

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- Figure 2 Scanning System
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- Figure 8 Printout of Image Stored in Computer Memory
- Figure 9 Tabular Printout of Coordinates of Four Curves
- Figure 10 Printout of Aerial Photograph - Left
- Figure 11 Printout of Aerial Photograph - Right

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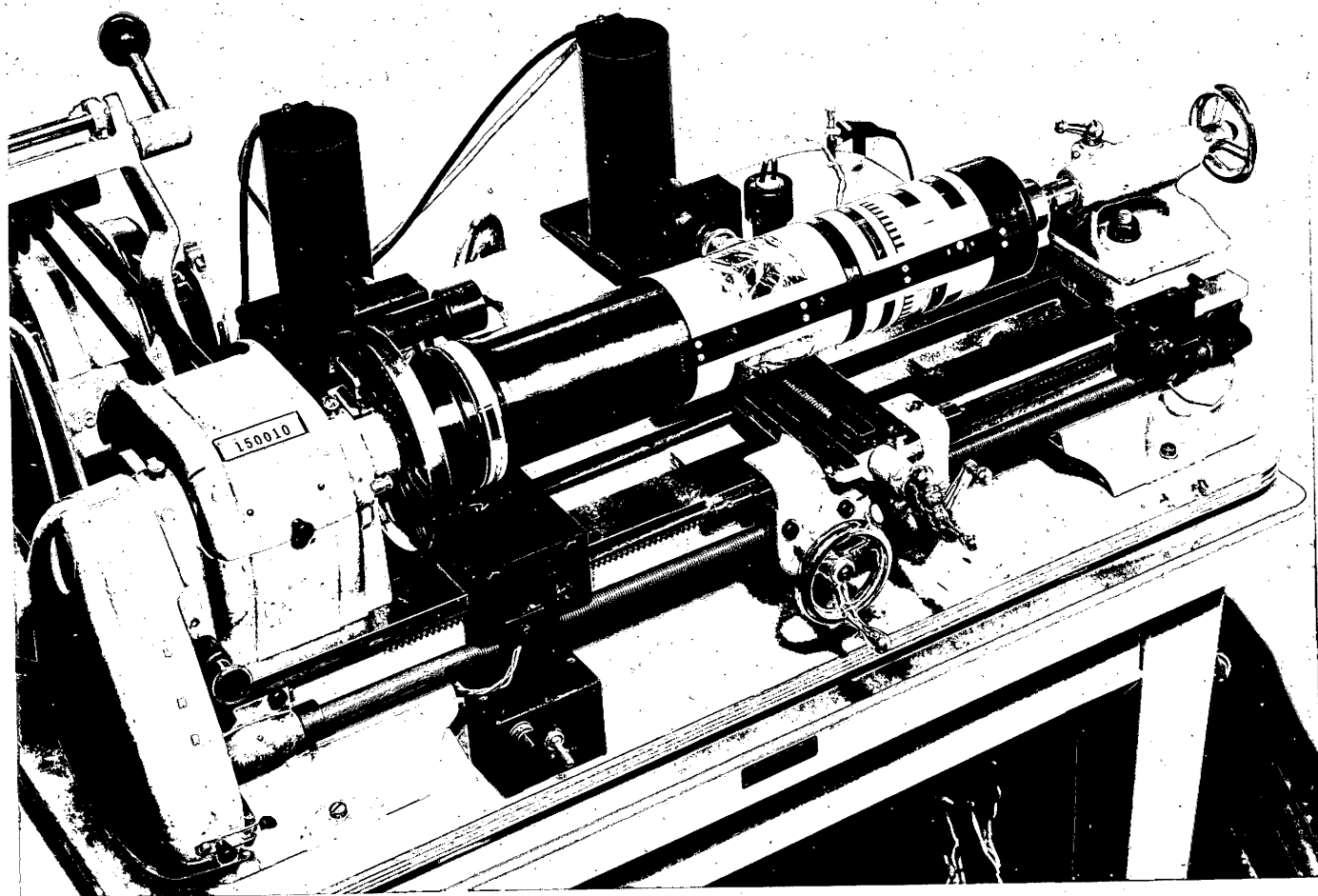


Figure 1. Photograph of the NBS Scanner

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SCANNING SYSTEM

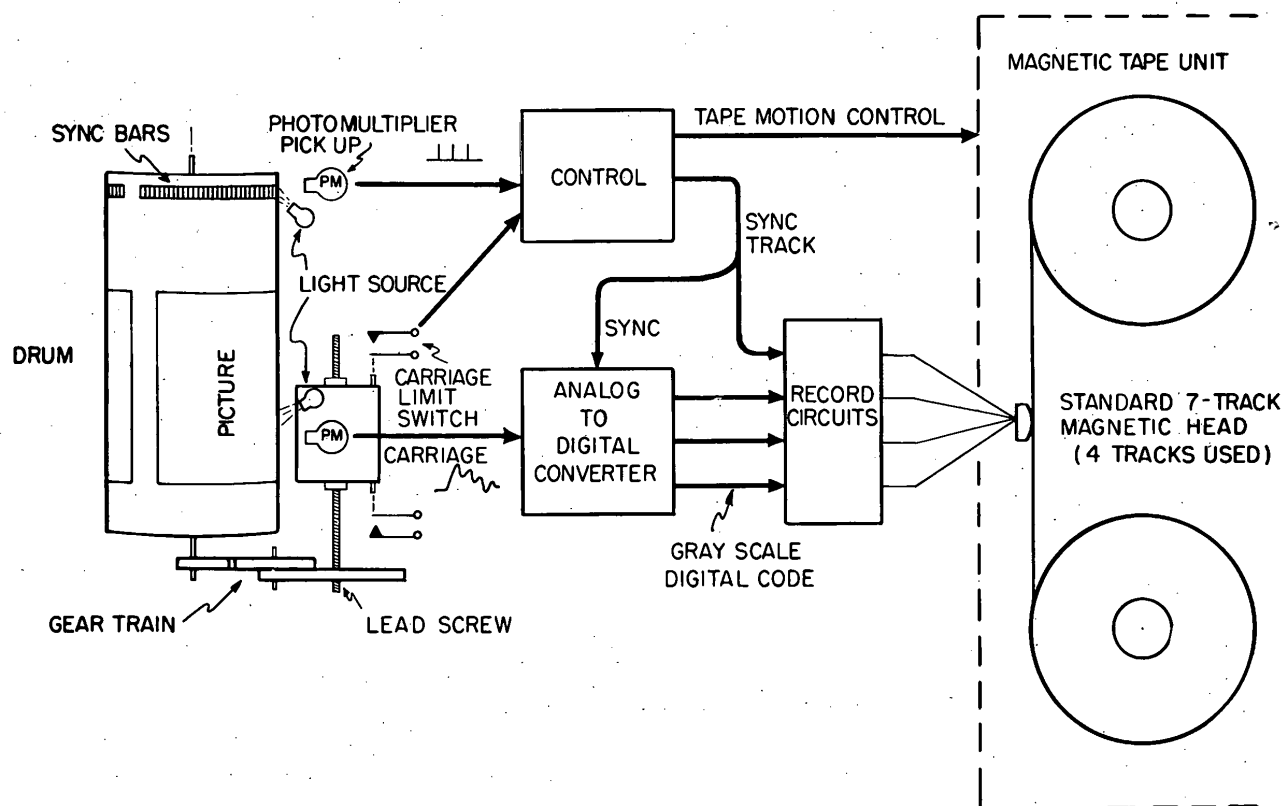


Figure 2.

OPTICAL SYSTEM OF SCANNER

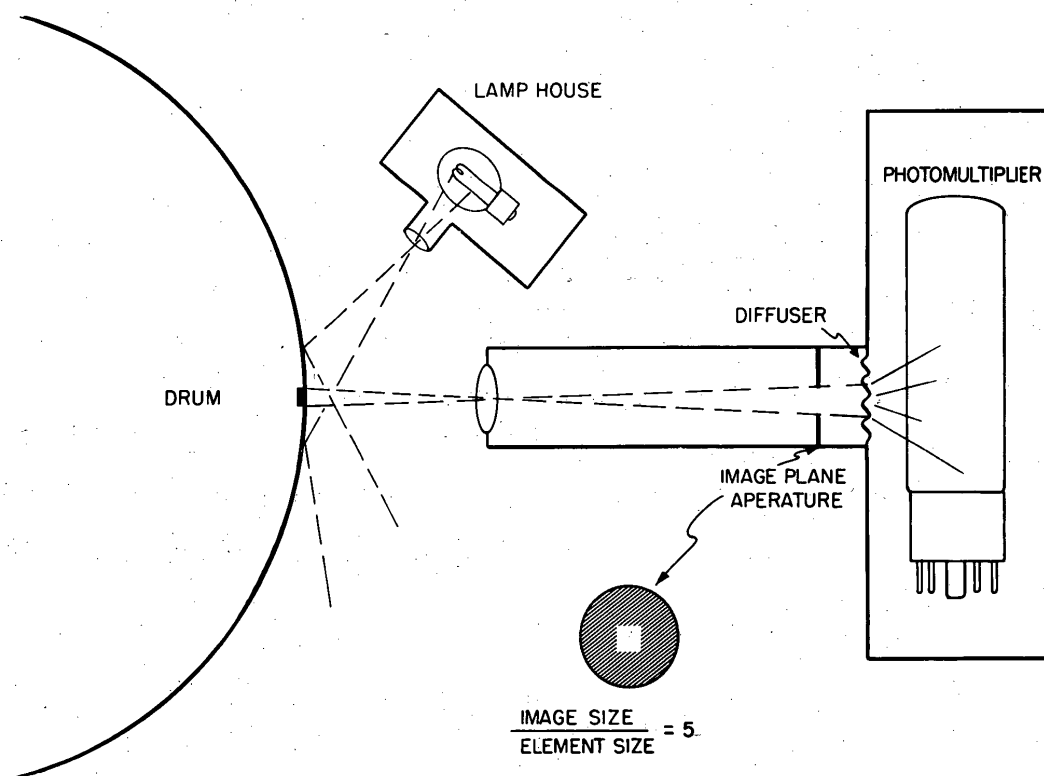


Figure 3.

CONVERSION OF PICTURE TO QUANTIZED GRAY SCALE

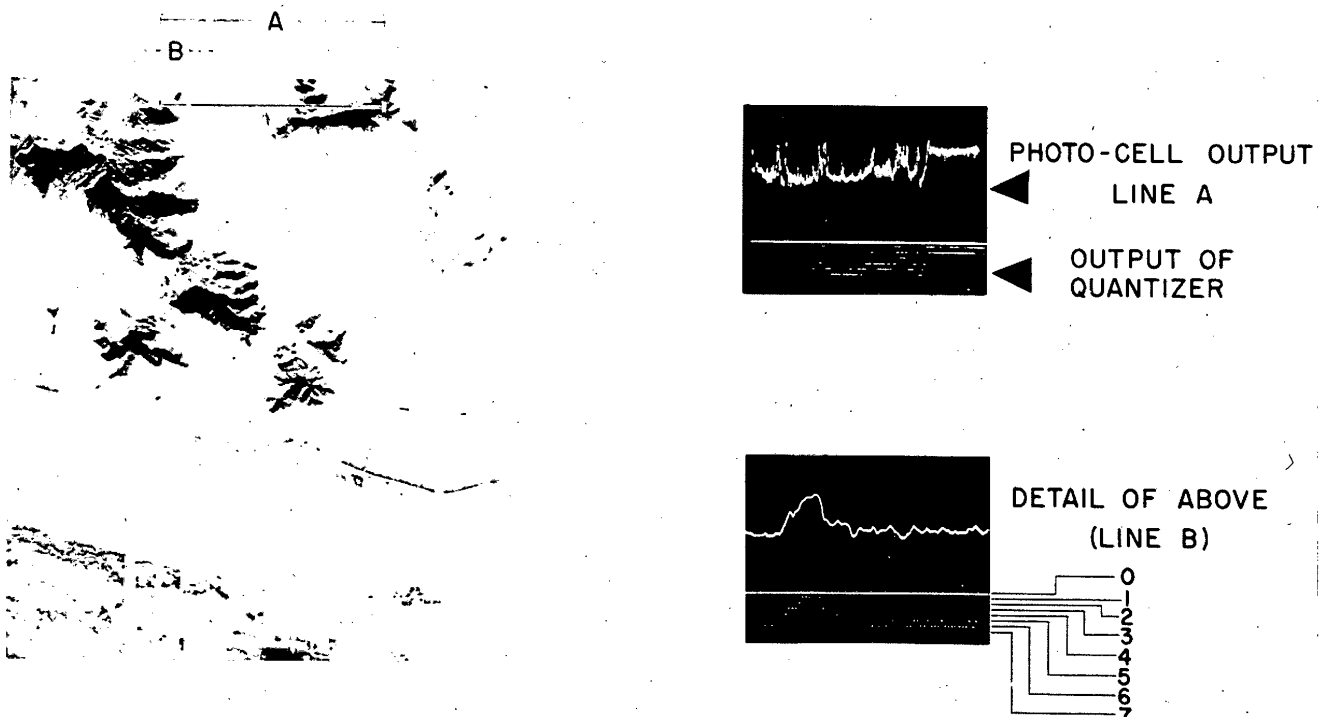


Figure 4.

RECORDING PICTORIAL INFORMATION ON DIGITAL MAG. TAPE

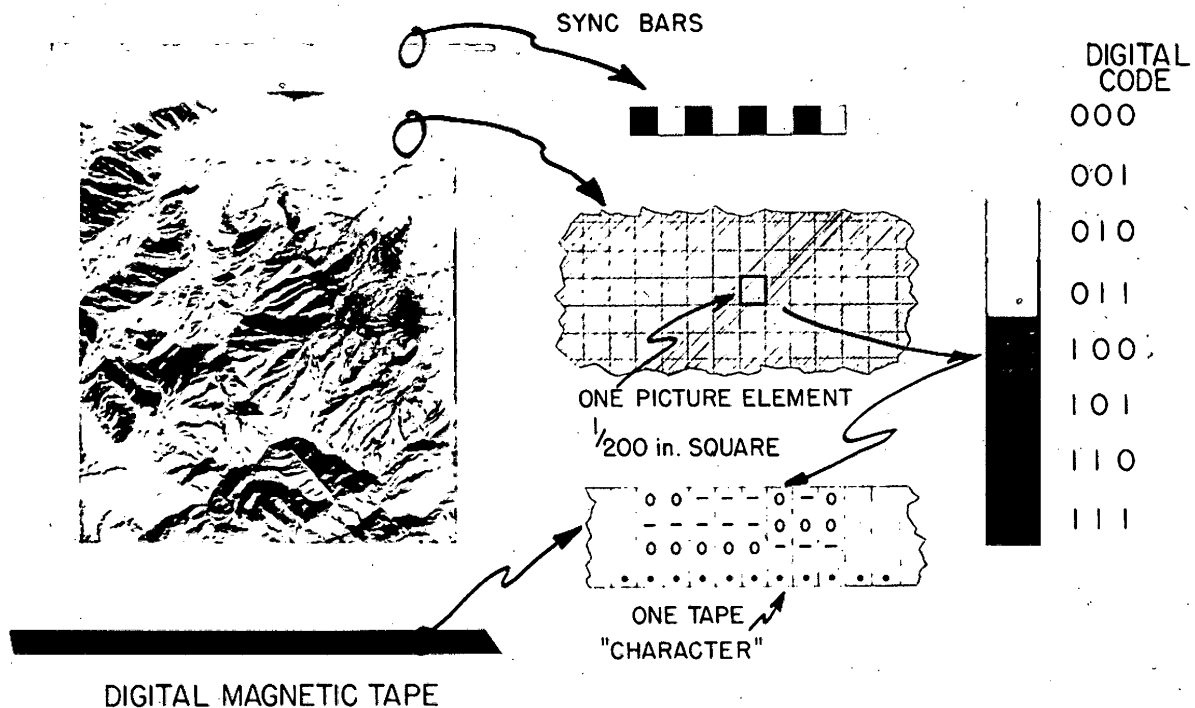


Figure 5.

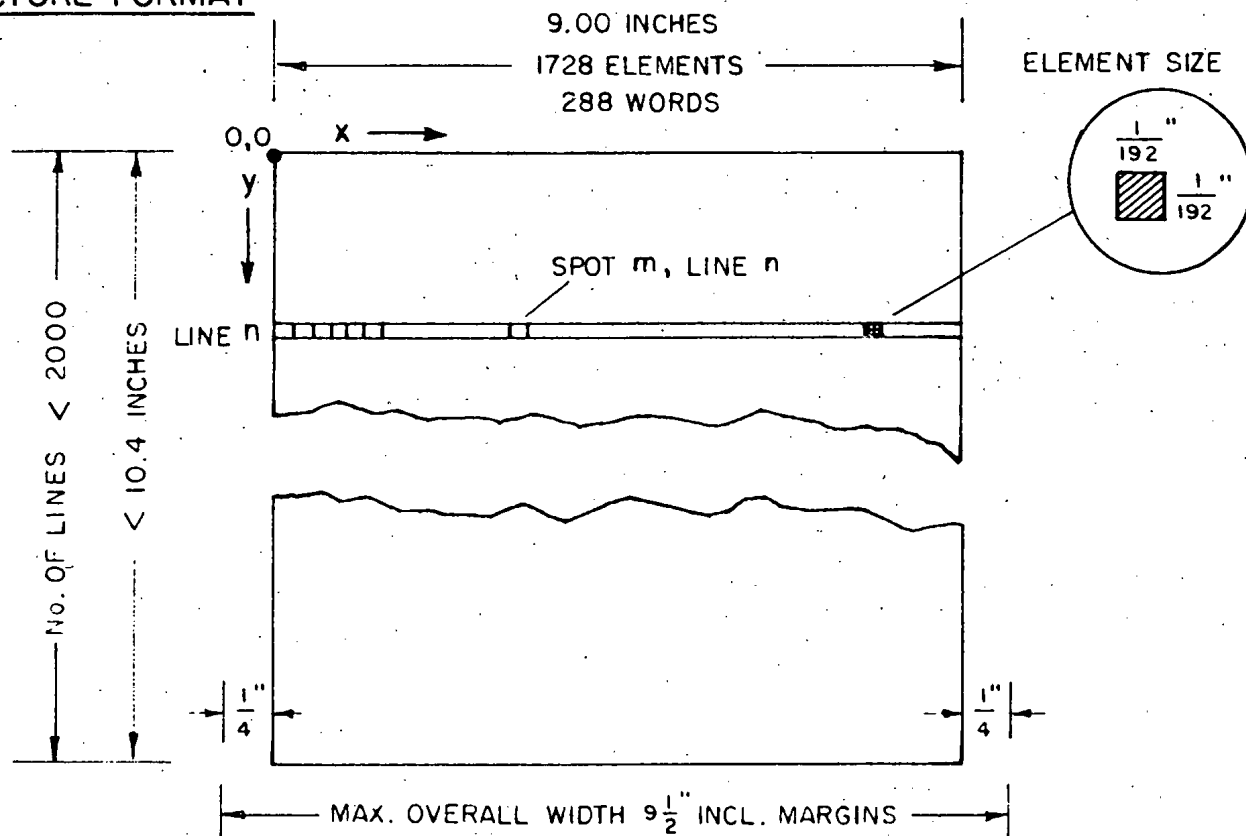
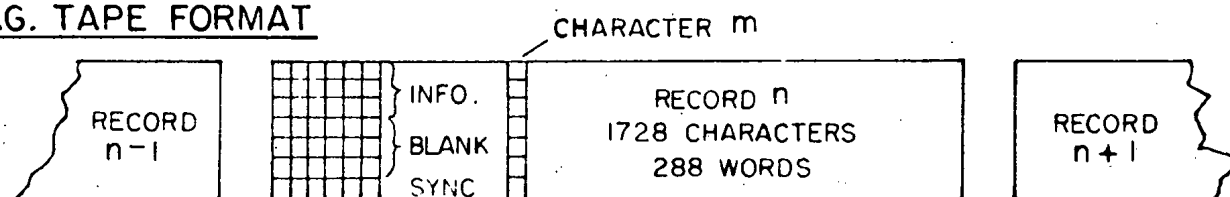
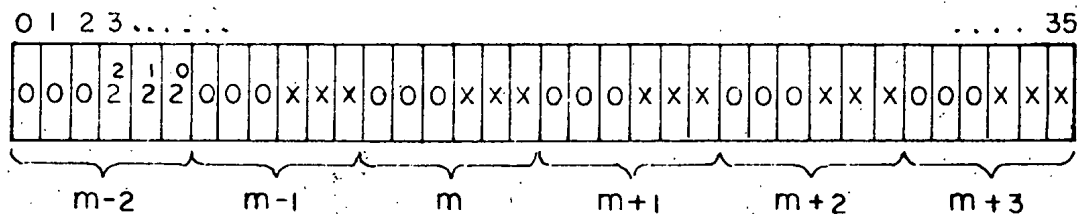
PICTURE FORMATMAG. TAPE FORMATCORE WORD FORMAT

FIGURE 6. RELATIONSHIPS BETWEEN PICTURE AND DIGITAL DATA FORMATS

Figure 7.

PRINTOUT OF IMAGE STORED IN COMPUTER MEMORY

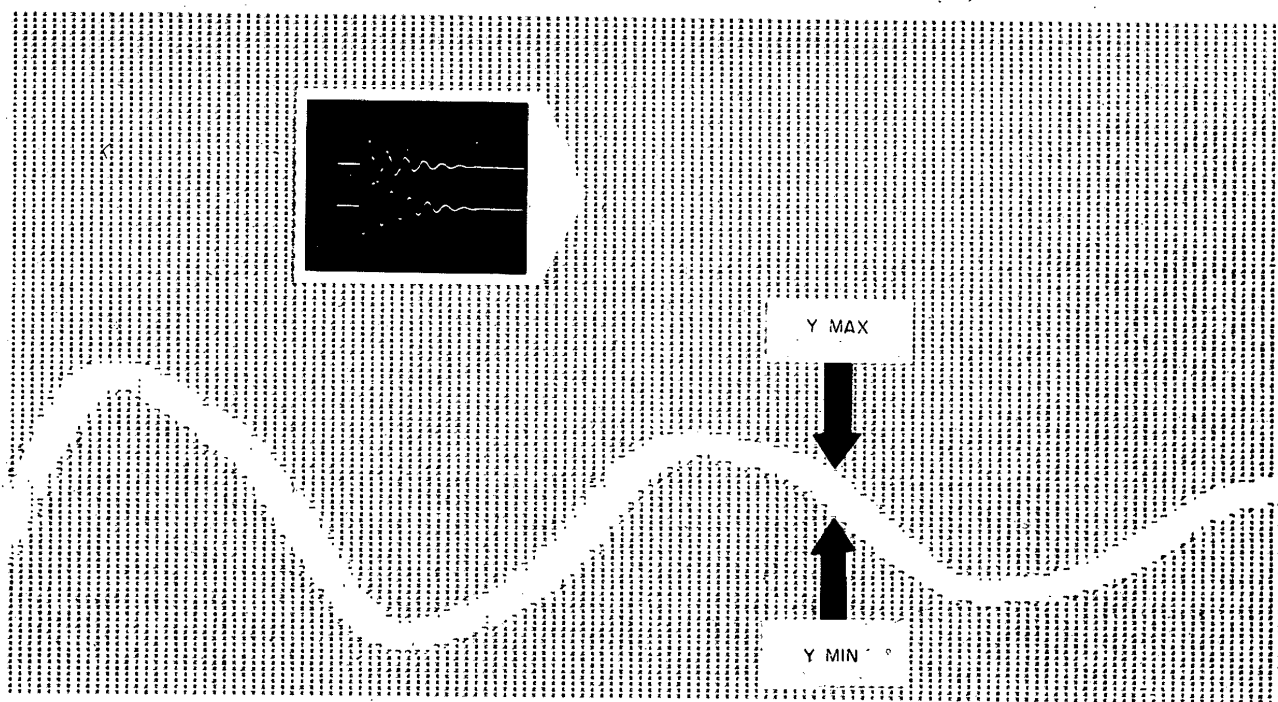


Figure 8.

X	CURVE 1		2		3		4	
	Ymin	Ymax	Ymin	Ymax	Ymin	Ymax	Ymin	Ymax
0184	0104	0108	0283	0294	0795	0798	0953	0956
0185	0104	0108	0285	0298	0795	0798	0952	0955
0186	0104	0108	0287	0303	0795	0798	0951	0955
0187	0104	0109	0292	0309	0795	0798	0950	0954
0188	0105	0111	0297	0315	0796	0798	0949	0953
0189	0105	0114	0302	0322	0796	0798	0947	0952
0190	0107	0118	0309	0328	0796	0798	0945	0951
0191	0109	0123	0315	0334	0796	0799	0943	0949
0192	0113	0127	0319	0338	0797	0799	0941	0947
0193	0117	0133	0324	0342	0797	0799	0939	0944
0194	0122	0139	0329	0344	0797	0800	0937	0942
0195	0130	0144	0333	0345	0798	0800	0936	0941
0196	0135	0151	0337	0345	0798	0800	0934	0938
0197	0143	0160	0340	0345	0799	0801	0933	0937
0198	0150	0166	0337	0346	0799	0801	0931	0936
0199	0157	0174	0337	0346	0799	0802	0930	0934
0200	0165	0180	0335	0345	0800	0802	0929	0933
0201	0172	0187	0332	0344	0800	0802	0928	0932
0202	0177	0193	0329	0342	0800	0802	0927	0931
0203	0183	0197	0327	0340	0800	0803	0927	0930
0204	0187	0200	0325	0337	0801	0803	0927	0929
0205	0191	0204	0323	0335	0801	0803	0926	0929
0206	0195	0207	0321	0332	0801	0804	0926	0929
0207	0200	0210	0319	0330	0801	0804	0926	0928
0208	0203	0212	0317	0327	0802	0804	0926	0928
0209	0206	0215	0315	0325	0802	0804	0926	0928
0210	0209	0216	0313	0323	0803	0805	0926	0928
0211	0211	0218	0310	0321	0803	0805	0926	0929
0212	0213	0218	0307	0319	0803	0805	0926	0929
0213	0214	0219	0304	0316	0803	0805	0926	0930

TABULAR PRINTOUT
OF COORDINATES OF FOUR CURVES

Figure 9.

250
700
100.

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250 TTTTTTXXXXXXX...
 260 NNNNNNNNNNN...
 270 NNNNNNNNNNN...
 280 NNNNNNNNNNN...
 290 NNNNNNNNNNN...
 300 NNNNNNNNNNN...
 310 NNNNNNNNNNN...
 320 NNNNNNNNNNN...
 330 NNNNNNNNNNN...
 340 NNNNNNNNNNN...
 REMARK PLEASE SAVE TAPE 504 ON A5
 PAUSE
 REMARK END OF NO-OVERFLOW
 WEF A3

P1J1
 8/7/63

250
 1250 1520
 100

Figure 11. Printout of Aerial Photograph - Right